SUB-STATION

Introduction:

The present day electrical power system is AC i.e. electric power is generated, transmitted and distributed in the form of Alternating current. The electric power is produce at the power station, which are located at favorable places, generally quite away from the consumers. It is delivered to the consumer through a large network of transmission and distribution. At many place in theline of power system, it may be desirable and necessary to change some characteristic (e.g. Voltage, ac to de, frequency p.f. etc.) of electric supply. This is accomplished by suitable apparatus called sub-station for example, generation voltage (11kv or 6.6kv) at the power station is stepped up to high voltage (Say220kv to 132kv) for transmission of electric power. Similarly near the consumer's localities, the voltage may have to be stepped down to utilization level. This job is again accomplished by suitable apparatus called sub-station.

Definition of sub-station:

"The assembly of apparatus used to change some characteristics (e.g. Voltage, ac to dc, frequency, power factor etc.) of electric supply is called sub-station"

Classification of sub-station:

There are several ways of classifying sub-station. These substations may be classified in numerous ways, some of the common ones are given below:

I) According to service requirement:

According to service requirement sub-station may be classified into:

1) Transformer sub-station:-

Those sub-station which change the voltage level of electrical supply are called Transformer sub-station.

2) Switching sub-station:-

These sub-stations simply perform the switching operation of power line.

3) Power factor correction sub-station:-

Those sub-station which improve the power factor of the system are called power factor correction sub-station. These are generally located at receiving end sub-station.

4) Frequency changer sub-station:-

Those sub-stations, which change the supply frequency, are known as frequency changer sub-station. Such sub-station may be required for industrial utilization.

5) Converting sub-station:-

Those substation which change a.c. power into d.c. power arecalled converting substation ignition is used to convert AC to DC power for traction, electro plating, electrical welding etc.

6) Industrial sub-station:-

Those sub-stations, which supply power to individual industrialconcerns, are known as industrial sub-station.

II) According to constructional features:-

According to constructional features, the sub-station is classified as:

1) Outdoor Sub-Station:-

For voltage beyond 66KV, equipment is invariably installed outdoor. It is because for such Voltage the clearances between conductor and the space required for switches, C.B. and other equipment becomes so great that it is not economical to install the equipment indoor. These substations are further subdivided into:

(a) Pole Mounted Substations: Such substations are erected for distribution of power in localities. Single stout pole or H-pole structures with suitable platforms are employed for transformers capacity up to 25 KVA, 100 KVA and above 100 KVA respectively.

(b) Foundation Mounted Substations: For transformers of capacity above 250 KVA the transformers are too heavy for pole mounting. Such substations are usually for voltages of 33,000 volts and above.

2) Indoor Sub-station:-

For voltage upto 11KV, the equipment of the substation is installed indoor because of economic consideration. However, when the atmosphere is contaminated with impurities, these sub-stations can be erected for voltage upto 66KV.

3) Underground sub-station:-

In thickly populated areas, the space available for equipment and building is limited and the cost of the land is high. Under such situations, the sub-station is created underground. Fig1. Shows a typical underground sub-station in which transformer, switch gear & other equipments are installed.

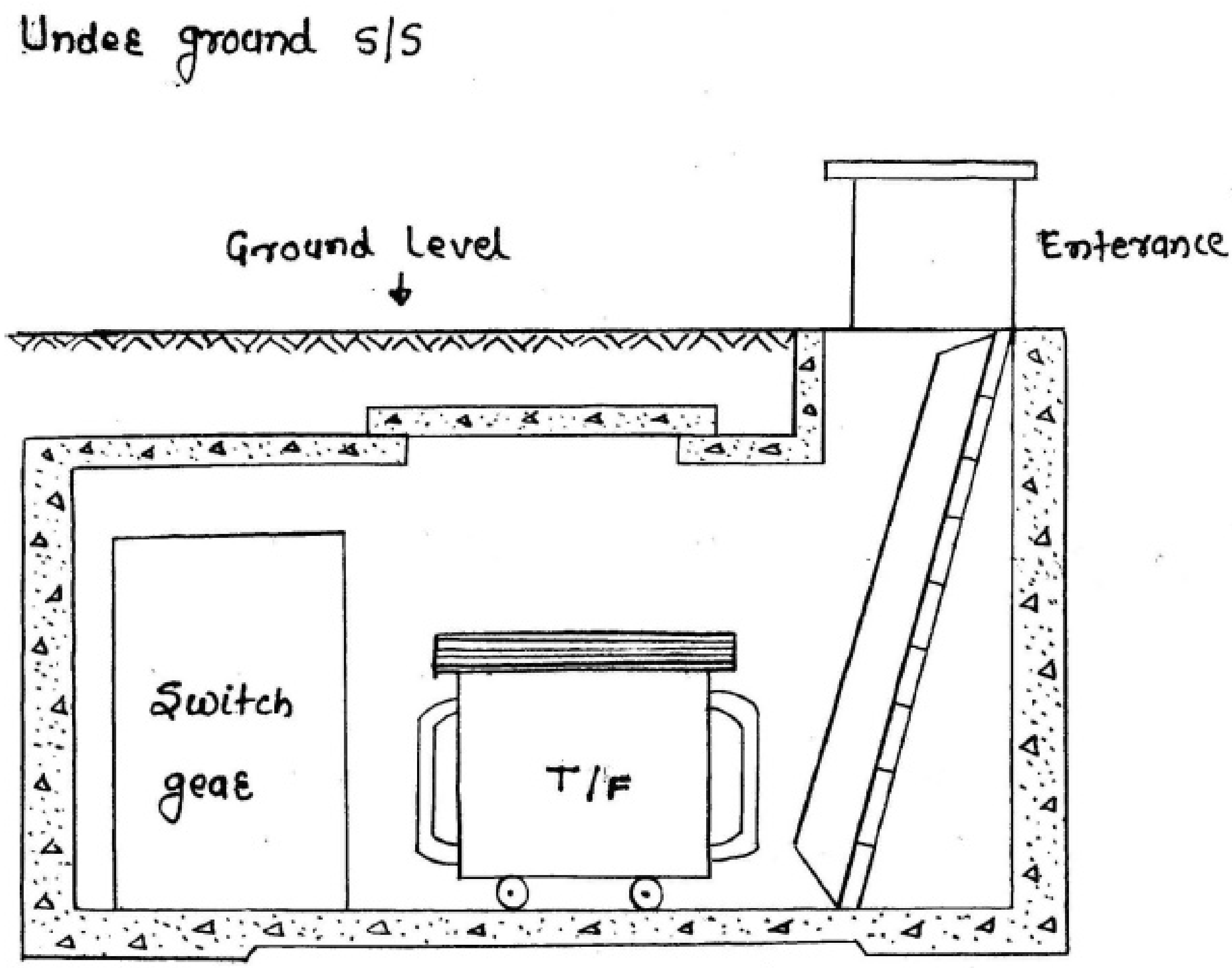

Fig1: A typical underground sub-station

The design of underground sub-station requires more careful consideration as:

1) The size of the sub-station should be as minimum as possible.

2) There should be reasonable access for both equipment & personal.

3) There should be provision for emergency lighting and protection against fire.

4) There should be good ventilation.

4) Pole-mounted sub-station:-

This is an outdoor sub-station with equipment installed overhead on H-pole or 4-pole structure. It is the cheapest from of s/s for voltage not exceeding 11KV(or 33KV in some cases). Electric power is almost distributed in localities through such sub-station.Fig2.shows the typical 4-pole sub-station, it is a distribution sub-station placed overhead on a pole.

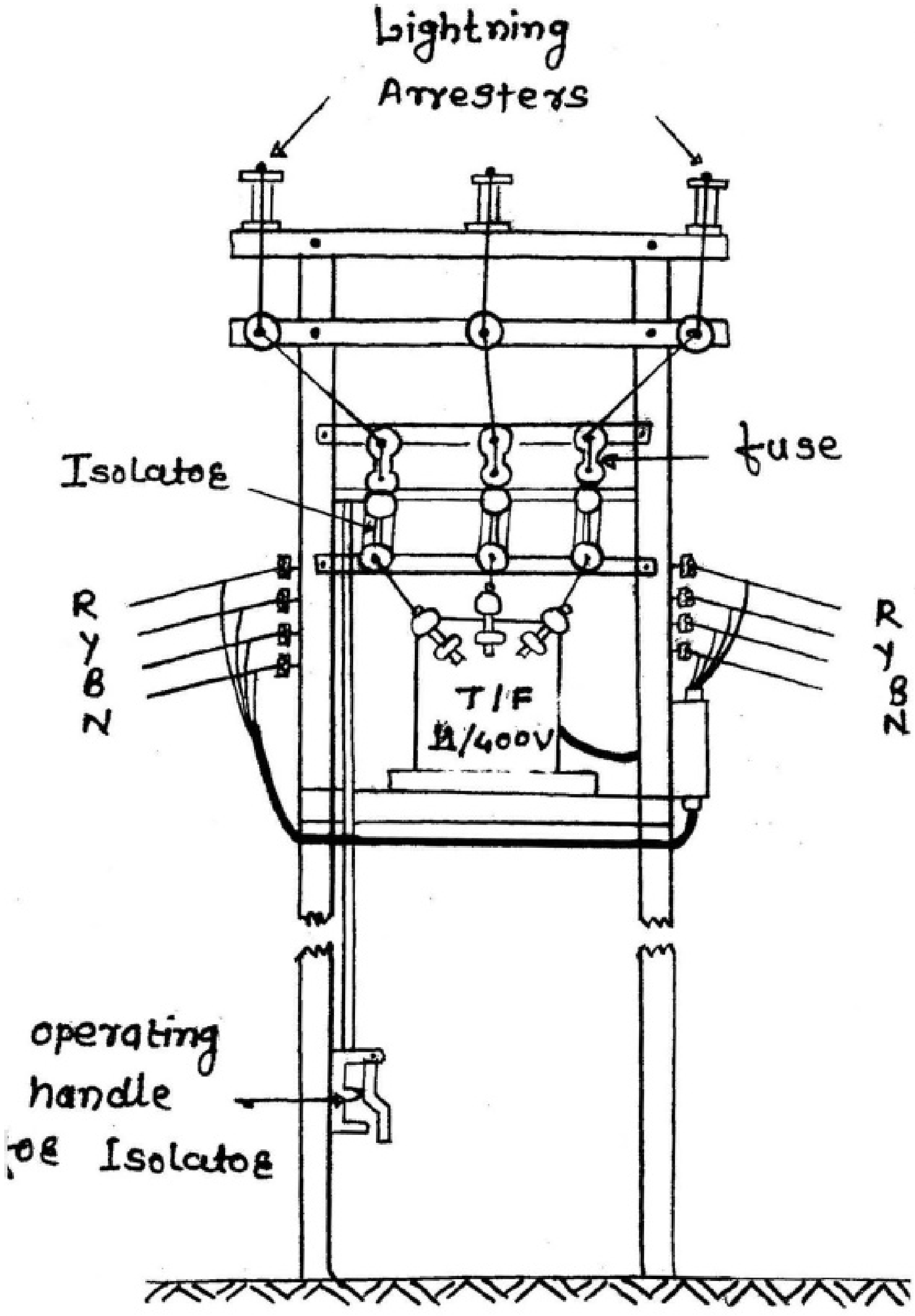

Fig2: the typical 4-pole sub-station.

The 11KV line is connected to the T/F (11KV/440V) through gang isolator and fuses. The lighting arresters are installed on the H.T. Side to protect the sub-station from lighting strokes. The Transformer step down voltage to 400V, 3 phase, 4 wire supply. The voltage between any two lines is 400 V & between line& neutral is 230V. The oil circuit breaker installed on the L.T. side automatically isolates the mounted sub-station. Transformers are generally in the event of fault generally 200KVA Transformers are used.

III) According to the nature of duties are classified into:

a) Step-up or Primary Substations where from power is transmitted to various load centers in the system network and are generally associated with generating stations.

b) Step-up and Step-down or Secondary Substations, may be located at generating points where from power is fed directly to the loads and balance power generated is transmitted to the network for transmission to other load centers.

c) Step-down or Distribution Substations receives power from secondary substations at extra high voltage (above 66 KV) and step down its voltage for secondary distribution.

lV) According to the basis of operating voltage:

(i) High Voltage Substations (HV Substations) involving voltages between 11 KV and 66 KV.

(ii) Extra high voltage substations (EHV Substations) involving voltages between 132 KV and 400 KV and

(iii) Ultra high voltage substations (UHV Substations) operating on voltage above 400 KV.

V) According to the basis of importance may be classified into:

i. Grid Substations:- These are the substations from where bulk power is transmitted from one point to another point in the grid. These are important because any disturbance in these substations may cause the failure of the grid.

ii. Town Substations:- These substations are EHV substations which step down the voltages at 33/11kv for further distribution in the towns and any failure in such substations results in the failure of supply for whole of the town.

Comparison between outdoor & indoor substation:-

Sr. No.	Particulars	Outdoor Sub-station	Indoor Sub-station
1.	Space required	More	Less
2.	Time required for erection	Less	More
3.	Future extension	Easy	Difficult
4.	Fault location	Easier because the equipments are in full view	Difficult because the equipment is enclosed
5.	Capital cost	Low	High
6.	Operation	Difficult	Easier
7.	Possibility of fault escalation	Less because clearance can be provided	More

Equipments in a Transformer Sub-Station:

The equipment required for a transformer Sub-Station depends upon the type of Sub-Station, Service requirement and the degree of protection desired. TIF Sub-Station has the following major equipments.

1) Bus-bar:-

When a number of lines operating at the same voltage have to bedirectly connected electrically, bus-bar are used, it is made up of copper or aluminum bars (generally of rectangular X-Section) and operate at constantvoltage.Fig. Shows the arrangement of Duplicate bus-bar, generally it consist of two bus-bars a “main” bus-bar and spare bus-bar. The incoming and outgoing lines can be connected to either b/b. With the help of a bus-bar coupler, which consist of a circuit breaker and isolators. However, in case of repair of main bus-bar or fault accusing on it, the continuity of supply to the circuit can be maintain by transforming it to the spare bus-bar for voltage exceeding 33KV, Duplicate bus-bar is frequently used.

2) Insulators:-

The insulator serves two purposes. They support the conductor (or bus bar) and confine the current to the conductor. The most commonly used material for the manufactures of insulators is porcelain. There are several type of insulator (i.e. pine type, suspension type etc.) and there used in Sub-Station will depend upon the service requirement.

3) Isolating Switches:-

In Sub-Station, it is often desired to disconnect a part of the system for general maintenance and repairs. This is accomplished by an isolating switch or isolator. An isolator is essentially a kniff Switch and is design to often open a circuit under no load, in other words, isolator Switches are operate only when the line is which they are connected carry no load. For example, consider that the isolator are connected on both side of a cut breaker, if the isolators are to be opened, the circuit breaker must be opened first.

4) Circuit breaker:-

A circuit breaker is an equipment , which can open or close a circuit under normal as well as fault condition. It is so designed that it can be operated manually (or by remote control) under normal conditions and automatically under fault condition. For the latter operation a relay which is used with a circuit breaker generally bulk oil circuit breaker are used for voltage upto 66 KV while for high voltage low oil & SF6C.B. are used. For still higher voltage, air blast vaccum or SF6 circuit breaker are used.

5) Protective relay:-

"A protective relay is a device that detects the fault and initiates the operation of the circuit breaker to isolate the defective element from the rest of the system".
The relay detects the abnormal condition in the electrical circuit by constantly measuring the electrical quantities, which are different under normal and fault condition. The electrical quantities which may change under fault condition are voltage, current, frequency and phase angle. Having detecting the fault, the relay operates to close the trip circuit of circuit breaker.

6) Instrument Transformer:-

The line in the Sub-Station operates at high voltage and carries current of thousands of amperes. The measuring instrument and protective devices are designed for low voltage (generally 110V) and current (about 5A). Therefore, they will not work satisfactory if mounted directly on the power lines. This difficulty is overcome by installing Instrument transformer, on the power lines. There are two types of instrument transformer.

i) Current Transformer:-

A current transformer is essentially a step-down transformer which steps-down the current in a known ratio, the primary of this transformer consist of one or more turn of thick wire connected in series with the line, the secondary consist of thick wire connected in series with line having large number of turn of fine wire and provides for measuring instrument, and relay a current which is a constant faction of the current in the line.

ii) Voltage Transformer:-

It is essentially a step - down transformer and step down the voltage in known ratio. The primary of these transformer consist of a large number of t urn of fine wire connected across the line. The secondary way consist of a few turn sand provides for measuring instruments and relay a voltage which is known fraction of the line voltage.

7) Metering and Indicating Instrument:-

There are several metering and indicating Instrument (e.g.Ammeters, Volt-meters, energy meter etc.) installed in a Sub-Station to maintain which over the circuit quantities. The instrument transformer is invariably used with them for satisfactory operation.

8) Miscellaneous equipment:-

In addition to above, there may be following equipment in a Sub-Station. i) Fuses. ii) Carrier-current equipment. iii) Sub-Station auxiliary supplies.

AUTOMATIC SUBSTATIONS:

The automatic substation is that we must look for developments in the future. The subject is one of increasing importance, and now that sufficient experience has been gained to prove that they are thoroughly reliable a very large increase in the number of unattended substations is likely to follow. During the war, when the shortage of labor made the maintenance of electrical supply a difficult business, many engineers turned their thoughts towards the automatic substation as a way out of their difficulties. Development, however, during the war was not possible, and it was not till October, 1922, that the first fully automatic station was set to work in Great Britain, this being supplied to the City of Liverpool by the Metropolitan Vickers Co. It is of course true that quite a number of fully automatic substations were running in America before that date, and the credit for the initial development lies with the United States. The increase in America is prodigious, and as a conservative estimate we may say that there are working there about 700 automatic substations controlling about 800,000 kilowatts and also many thousands of automatic reclosing feeder installations.

Selection of positions for automatic substations, the number required, size and type of plant installed, and the various automatic systems that are in use at the present time. When Automatic Stations are Justified. First of all it is necessary to come to a decision as to whether the installation of automatic substations is justified, and every case must be dealt with on its own merits. This decision is not an easy one to come to, as so many factors are involved ; but one point stands out clearly, that those systems which are bound to continue supplying at a low voltage, say 100 volts two-wire or 100 volts three-wire(200 V. across outers), will require automatic substations first and will reap the most benefit from their use. The reason for this is fairly obvious, that beyond a certain point it is impossible to continue to supply from existing manual substations, as the cost of laying the extra mains to deal with the load becomes prohibitive and the pressure drop is so great that complaints are bound to arise. It is a very extraordinary fact that such a go-ahead nation as America has standardized on a voltage of 115. This voltage was originally chosen because 115-volt lamps were more reliable and economical than 230-volt, but with the improvements that have been made in lamp manufacture this advantage has largely disappeared. On the other hand, the disadvantage of such a low voltage as 115 is now making itself felt more every day as the load increases so rapidly. Converting plant for the voltage is much more expensive ; it is less efficient ; the expenditure in copper in the mains is enormous and the range of supply is much more restricted. We can only assume that they are so deeply committed to this voltage by reason of the number of schemes using it that they cannot face any change. Probably also the standardization of lamps, fittings, motors, etc., for this voltage is so complete that the financial loss in making a change would be prohibitive. It is probably these facts which have led to the very much larger use of automatic substations in the United States. If, however, we take a system, of which there are many in this country, which runs at 240-volt three-wire (480 across outers), and assuming the same current and the same section of feeders in the two cases, we can convey 2-4 times the kW. for 2-4 times the distance for the same percentage drop of volts, or, to put it another way, we can carry for a given percentage drop of volts the same power (2-4)2 = 5-75 times the distance. In the latter case, especially if there are plenty of spare ducts into which feeders can be pulled, the justification for automatic substations is not nearly so obvious, and it will pay to continue increasing the plant in the large manual stations for a very much longer period.

Increased Capacity of Mains Network: There will come a time, however, when this is no longer economical, and this time is brought nearer by another consideration, viz. the improvement in the capacity of the existing mains produced by installing an automatic substation say midway between two existing manual substations. If we take the lighting and power supply to a large town with manually operated substations containing a good deal of plant spaced as equally as possible over the whole area, it is obvious that feeders from these substations must vary considerably in length and there comes a time when the drop on the long feeders due to increased load is too great ; if the bus bar pressure is increased to compensate for this drop, the shorter feeders will be at too high a voltage. It is here where the automatic substation comes to our assistance. By putting in such a station at the point where the pressure is low, one is enabled to take this load over from the manual station, thus allowing this station to lower its bus bar pressure. By cutting the long feeders into two pieces and connecting up the far end into the automatic substation, we thus have two feeders made out of the one. If the feeder from the manual station is connected to the network at its new feeding point, it will carry a much larger current than previously without unduly increasing the pressure on the shorter feeders. We therefore see that the introduction of an automatic substation at a selected point enables the existing mains to be utilized to a much greater extent, and the saving in new mains will go a good way towards paying for the automatic substation. The cost of mains laying in large towns is becoming greater every year, as the congested state of the streets renders it necessary to go much deeper than was formerly the case.

Any scheme, therefore, which will do away with the necessity for new mains and will render the existing ones more effective is well worthy of consideration.

Selecting Positions for Automatic Substation: The best position for an automatic substation is fairly easily determined by an examination of the recording voltmeter charts which indicate the pressures at the various points in the system, and we now have to consider the number of stations to be installed and the capacity of each. Some engineers may be tempted by the fact that they can obtain a site for a large automatic substation at a given spot to install a considerable number of machines in this one station, making it of a capacity which is comparable with the manual stations. This is a mistake from several points of view: -firstly, the increased capacity of existing mains is not obtained in the same way as would be the case if the same amount of plant was distributed over two or three substations ;

secondly, the advantage claimed for automatic substations, viz. the saving in wages of attendants, is not obtained to the same extent as if two or three stations were put in. Moreover, the interest on the cost of the automatic gear required for a considerable number of machines in one substation may be greater than the saving by not having attendance in that one C2 v C2 station. Some engineers take the line that automatic substations should not contain more than one set ; but without agreeing to this statement the author is of the opinion that two sets, or at the most three, is the maximum number that should be allowed.

Capacity of Plant: Now as regards the capacity of the sets installed, it should be remembered that the cost of the main part of the automatic gear, the relays, etc., is the same for a small machine as for a large one, and that two machines each giving 500 kW cost very much more than one machine giving 1,000 kW.

From the above it is clear that the thing to aim at is to put in the largest capacity machine that can be justified by the load which has to be dealt with. There is really no limit to the size of machine which can be started up automatically, and in the case of traction systems where the automatic principle is adopted throughout, sets of 3,000 and 4,500 kW. are employed with perfect success.

In the case of automatic hydro-electric stations sets of 9,000 kW are started up and switched in entirely without human agency.

Types of Converter: The rotary converter is the most usual type of machine employed, but motor converters are coming more into favor because the transformer with its possible fire danger is not needed and the space occupied is less.

In the case of traction systems working at 1,500 and 3,000 volts the double-ended motor generator and the mercury arc rectifier are installed, and both types lend themselves admirably to automatic operation.

For small capacity stations in outlying districts, particularly in residential neighborhood where the noise made by running machinery might be objected to, the glass bulb rectifier is utilized, and in this case automatic regulation of the voltage is possible by varying the tap connections on the transformers. In automatic stations controlling running machinery, whether rotary converter, motor converter or motor generator is used, the starting-up arrangements are very similar and a standard type of station with slight modification for the different types of plant can be evolved.

This is a considerable advantage, as an engineer can install different types of plant throughout his system, according to the necessity of the situation, and yet use the same automatic apparatus, thus simplifying the work of the inspection engineers. This question of standardization of apparatus becomes of increasing importance as the system grows, and if all the apparatus in all the stations is the same the number of spares needed is much less. There are a considerable number of systems already in existence for the automatic control of rotating converting plant both for partial and for full operation.

Although in some cases, owing to the existence of a considerable number of pilot wires between the manually operated and the automatic station, a number of operations can be started by merely pressing a push-button, it is now generally accepted that this partial control is not the best practice and that the whole of the process from the starting of the machine until it is connected to the D.C. busbars is far better left to automatic operation.

This is termed a fully automatic substation: A system of supervisory control in connection with a fully automatic station is the most approved arrangement at the present time, as while it possesses all the advantages of automatic starting and regulating, etc., it enables a control to be exercised in the time of starting up and shutting down and also the switching in and out of D.C. feeders.

Therefore, proposes to deal mainly with the fully automatic systems, and will describe three types made by the Metropolitan Vickers Co., the British Thomson- Houston Co., and the Brown Boveri Co. (Mercury Arc Rectifiers).

THE B.T.H. SYSTEM OF AUTOMATIC CONTROL:

The special features of this system are :

(1) The motor-operated master controller ensures the correct sequence of switching operations under all conditions. This consists of a cylindrical drum driven by a small A.C. commutator motor, the speed being reduced by means of worm-wheel gearing, so that one complete revolution of the drum occupies about fifty seconds. The drum carries a number of circumferential contact strips, which, as the drum rotates, make contact with fixed-contact fingers. These strips are interconnected in such a way that the various control circuits are only closed and opened in one definite sequence. This method of fixing the sequence is claimed to be superior to the ordinary electrical interlocks, as the chances of failure are very small, and a good wiping contact is always assured.

(2) The auxiliary generator, which is driven from the rotary converter shaft, and which by means of an auxiliary field winding on the rotary converter, fixes the polarity, and prevents the necessity of reversing the field, if it comes up in the wrong direction.

(3) Induction motor for starting, which does away with the necessity for the brush raising gear required where the rotary is tap started.

The sequence of operations is as follows :

Starting: This can be initiated in several ways:

(1) When the load increases so that the D.C. pressure falls below a certain fixed figure, a master starting element comes into operation, and makes a contact which starts the automatic operation.

(2) By a manually-operated master control switch in some distant control room.

(3) By a time switch.

(4) By closing a high-tension feeder switch at the power station, or some other point. Whichever-method is used, the closing of the necessary contact energizes a master control contactor through a time-delay relay. The relay is included to prevent the equipment starting up due to momentary fluctuations of line voltage. The master control contactor is so interlocked, that it cannot close unless the motor-operated controller is in the "off" position.

The closing of the master control contactor causes the motor-operated controller to rotate, thereby closing the high-tension oil circuit-breaker ; the main power transformer is now energized. Further rotation of the controller closes a "starting" contactor, and at the same time connects an auxiliary field winding on the rotary converter to an auxiliary generator which is driven from the rotary converter, shaft. The starting contactor energizes the starting motor, and the machine starts. At this point the controller stops and waits for the machine to synchronize.

As the rotary converter accelerates, the auxiliary generator builds up its voltage, thus energizing the auxiliary field winding, and fixing the polarity of the machine.

As the voltage of the auxiliary generator builds up, the motor driving the motor-operated main field rheostat, starts and rotates the rheostat arm to the "all in" position.

When the voltage attains approximately 80 per cent, normal, the synchronizing field contactor closes, thereby adjusting the resistance in the main field of the converter to the correct value for synchronizing.

When synchronism is reached, a synchronous speed indicating relay operates and re-starts the master controller, thus closing a "running" contactor, and connecting the machine direct to the transformer, whilst the main field is disconnected from the synchronizing tapping on the field rheostat and connected to the moving arm of the rheostat. A "neutral" contactor also closes, thereby connecting the mid-point of the power transformer to the neutral of the B.C. system. This is followed by the opening of the "starting" contactor. It will be noticed that the latter does not break circuit it is only called upon to make circuit.

At the same time as the starting contactor opens, the auxiliary field winding is disconnected from the auxiliary generator. The controller now waits until the motor driven rheostat has reached the "all resistance in" position, as mentioned above. When this operation is complete, the controller continues to rotate, thereby preparing the coil circuits of the line contactors for final closing. The controller ceases to rotate when it reaches "the running" position. Meanwhile, a voltage equalizing relay causes the field rheostat arm to rotate from the "all resistance in "position, until the voltage of the machine is equal to, or slightly greater than, that of the line, when the relay operates and closes an auxiliary contactor, which in turn permits the line contactors to close. When the machine is connected to the line, a voltage regulating relay controls the voltage.

The rotary converter continues to run, and supplies power until shut down by an under load, or by the operation of one of the protective devices. When the load on the machine falls to a predetermined value, an under load relay operates, thereby energizing a time-delay stopping relay. The 'time delay feature incorporated in the latter relay prevents a shut-down due to a momentary fluctuation of load.

When the period of time for which the relay is set has expired, the relay operates and interrupts the coil circuit of the master control contactor, thus causing the latter to open.

This in turn causes the immediate disconnection of the machine from the D.G. bus bars by interrupting the coil circuits of the line contactors.

A normally closed contact on the master control contactor, provides a circuit to ensure that the master controller is immediately rotated to the "off" position.

As the controller rotates to the "off" position, it interrupts the coil circuit of the running contactor, thus disconnecting the machine from the power transformer ; it also completes the trip coil circuit of the high-tension oil circuit-breaker, which opens, thereby disconnecting the power transformer from the main transmission line. The master controller finally comes to rest in the "off" position, and the equipment is then ready to re-start when required.

Control and Protective Devices: Overloads and Short Circuits. The rotary equipment is protected against overloads and short circuits by means of overload relays operating in conjunction with a controlling relay of the repeat action pattern, which can be set for any number of "notches" up to six.

When an overload or short-circuit occurs, one (or both) of the overload relays operates, and causes the line contactors to open : simultaneously the repeat action relay which, is provided with a timing device advances one "notch."

The switch arm of the motor-driven field rheostat is then rotated to the "all in" position ; the voltage of the machine is then equalized with the line voltage, and the line contactors automatically re-close.

Should the line breakers remain closed for a period equal to the time setting of the repeat action relay, the notch is reclaimed. If, however, the fault persists, the line contactors are again opened by the action of the overload relay, and the cycle of operations is repeated. This cycle will continue until the repeat action relay has advanced to the last notch for which the relay is set, and will then finally operate its contacts, thereby shutting down the equipment until such time as the fault has been cleared and the relay re-set by hand.

Over speed: The rotary converter attain an excessive speed, the equipment is shut down by an over speed device, and locked out of commission until inspected.

Should the A.C. voltage be too low, the equipment is prevented from starting by the A.C. under voltage relay. Should the A.C. voltage fail during running, the machine is shut down by the operation of the same relay. The relay will re-set when normal voltage is restored, thus leaving the equipment free to go through its sequence, and to reconnect the machine to the D.C.

Bus bars. Single-Phase Starting. The equipment is prevented from starting, unless all three phases of the high-tension supply are energized, by a single-phase starting protective relay. Should the automatic control gear fail to connect the machine to the D.C. bus bars in a predetermined time, the converter is shut down and locked out, pending investigation by the operation of a sequence timing relay.

Overheating of Machine: A temperature relay, possessing the same heating and cooling characteristics as the machine, is provided, which shuts down the machine when, due to a sustained overload, the temperature of the machine has risen to a predetermined value. This relay will allow the machine to re-start when the latter has sufficiently cooled. Failure of D.C. Supply for Control Circuits. Should the auxiliary generator fail to build up its voltage, the line contactors, which obtain their control current from this generator, would fail to close, thus the equipment would be shut down by the sequence timing relay. Should the auxiliary generator lose its voltage during running, the line contactors would open, thus disconnecting the machine from the D.C. busbars ; after the time setting of the sequence timing relay has expired, the equipment would shut down.

Earth Leakage on D.C. Side: The D.C. earth protective relay shuts down the set should a flash to earth occur, or the insulation of the windings break down with an earth through the frame. This relay, being hand re-set, the equipment remains out of operation until the fault has been investigated.

Wrong Polarity: The inclusion of the auxiliary field winding separately excited from the auxiliary generator, ensures that the rotary will build up with correct polarity.

The auxiliary generator is disconnected from the auxiliary field when the rotary is in service, to prevent any disturbance being transmitted to the auxiliary generator ;consequently the auxiliary generator always correctly excites the rotary when the latter is started up.

Hot Bearings: Bearing temperature relays shut down and lock out the machine, should any of the bearings become overheated.

Overheating of Starting Motor: Should the starting motor overheat due to too frequent starting, or failure of the rotary converter to synchronize properly, the plant is shut down and locked out of commission by the starting motor temperature relay, until the cause of the trouble is removed and the relay re-set by hand.

Reverse Power on D.C. Side: Any tendency of the rotary converter to run inverted, is prevented by the D.C. reverse power and under load relay. This relay being self-resetting, allows the converter to re-start when necessary.

Overload or Earth Leakage on A.Q. Side: The high tension oil circuit-breaker is provided with time limit overload trip coils, and an earth leakage trip. Excessive A.C. overloads or earth leakage will trip this breaker, with the result that the machine is completely disconnected from both A.C. and D.C. sides. These trips are only intended to operate on very serious faults as being hand re-set they necessitate inspection before the equipment can again be put into commission.

THE METEOPOLITAN-VIOKERS AUTOMATIC CONTROL SYSTEM :

This method differs from the B.T.H. in that the system is self-contained, and does not employ a separate motor operated controller, that no dependence is placed upon time lags only, or upon any mechanical sequence of operations, but that each operation depends on the proper completion of the preceding operation. No auxiliary generator is employed for exciting the field of the rotary and thus fixing its polarity, but wrong polarity is corrected in five seconds by -a field reversing relay.

The tap-starting method is usually employed with rotaries, and this necessitates the provision of a brush lifting device. The starting up of the plant can be initiated in the same way as in the case of the B.T.H. system. The complete sequence of starting takes from thirty-five to fifty-five seconds, depending upon the capacity of the plant, and on whether the rotary runs up with the correct polarity or not. Operations in starting. The actual operations in starting are briefly as follows:

1. On the occurrence of some predetermined condition, close the high tension oil switch and excite the step down transformer.

2. Close a contactor connecting the rotary on to the first low-tension transformer tap.

3. Check polarity on the D.C. side and if necessary reverse the shimt field connection to get correct polarity.

4. Close a contactor connecting the rotary on to the full voltage terminals of. the transformer, after opening the contactor on the tap connections.

5. Connect the D.C. side of the rotary to the bus bars through a load limiting resistance.

6. If the current drawn on the D.C. side is not excessive, short-circuit the resistance, and connect the rotary direct on the bus bars.

Operations in Stopping: The procedure in stopping is simpler. The rotary being disconnected from, both D.C. bus bars and high-tension supply after expiration of the time lag in less than two seconds. The actual operations in stopping are as follows :

1. When load drops to a predetermined value, a time limit device comes into operation to ensure the plant does not close down merely to fluctuations in the load.

2. The control bus bars are de-energized.

3. All D.C. and A.C. relays and contactors, and the main oil switch open, and the plant is entirely out of

service.

Protective Features: An important feature of the apparatus is the inclusion of a complete range of automatic devices that give ample protection from possible troubles originating either inside or outside the substation. The arrangements are such that either the apparatus must function correctly, or automatically the protective devices either close down temporarily that portion affected, 01 permanently close down and lock out the whole equipment, depending upon the nature of the fault. In the latter case, the equipment remains shut down, until by the visit oil an inspector the cause of failure to operate has been discovered and rectified.

Starting Sequence Protection: If for any reason the machine is not running correctly within two minutes starting, the machine is locked out.

A.G. Overloads: On the A.C. side overload relays an operated only by heavy overloads. D.C. Overloads. On the D.C. side overload or current limiting relays insert resistances in the machine circuits to restrict current to one and a half times full load current.

Rotary Heating Protection: A thermal relay having temperature characteristics similar to those of the machine protects against sustained or repeated overloads, but allows machine to re-start when sufficiently cool.

Bearing Heating Protection: A thermostat in each machine bearing shuts down and locks out the machine should a bearing reach a dangerous temperature.

Resistance Heating Protection: A thermostat is mounted above the load-limiting resistance. It will close down the machine should the resistance overheat, but allows the plant to function again as soon as the temperature becomes normal.

Phase Unbalancing: A phase balance relay guards against both broken lines on the H.T. supply, and faults on the A.C. low-tension apparatus.

Reverse-Phase and Single-Phase Running: Protection is afforded against both these faults.

Low AC Voltage: Protection is afforded both when starting up and when running against a low voltage.

No Field: If the field of the rotary fails, the machine is disconnected from the D.C. bars.

Over speed: A speed limit device mounted on the rotary prevents excessive speed. Reverse Current on DC side. A reverse relay prevents reverse current operation.

THE MERCURY ARC RECTIFIER AUTOMATIC SUBSTATION:

It must be admitted that the starting up of a mercury rectifier is a far simpler operation than the starting up of any other type of converting plant, and when we come to automatic operation, the simplicity of the apparatus required is still further emphasized. No running up to speed or synchronizing is necessary, no provision for reversing the field in order to correct the polarity, and the set is in commission in about ten seconds.

On the other hand, it should be pointed out that this simplicity is due to some extent to the fact that the mercury rectifier itself has no regulating properties, and if regulation is necessary, an induction regulator has to be inserted in the case of the high-power rectifiers and motor controlled tap changing in the case of the glass-bulb type.

This involves additional switches, motors, and relays, and certainly makes the gear less simple. Even allowing for the regulation, however, the mercury arc rectifier automatic substation is very much simpler than the other types.

The starting of the rectifier is initiated by a time switch, which energizes a relay, and thus causes the motor control to operate the E.H.T. switch. Auxiliary contacts mounted on this switch cause the ignitior and excitation circuits of the rectifier to be closed, and the automatic valves for the circulating water to be opened. As soon as the current in the excitation arc flows, it closes an interlocking relay, which brings the apparatus in connection with the closing of the D.C. switch into operation.

First a relay closes, which tests to see whether the load is too heavy for the rectifier, or whether there is

Short-circuit ON: If either of these conditions exist, the DC switch will not close. If, however, the circuit is normal, the D.C. switch closes and the rectifier is in service. If there is a short-circuit on the system, the automatic apparatus attempts at intervals of one-quarter, one, three and eight minutes, to close the circuit, and if the short circuit still persists, the switch is locked out, and alarm signals are actuated.

When the short-circuit clears, a push-button, which may be controlled from a distant point, enables the interlock of the switch to be released, and the plant to be set in operation again. In the event of the rectifier attaining too high a temperature, owing to the flow of the circulating water being interrupted, a contact thermometer actuates a relay, and locks the rectifier out of circuit.

THE END